

Correspondence

Reply to "Concerning "Odd-Harmonic Digital Repetitive Control of a Single-Phase Current Active Filter""

Ramon Costa-Castelló, *Member, IEEE*, Robert Griño, *Member, IEEE*, and Enric Fossas

The main objective of this correspondence is to clarify several comments appearing in [1] about our work [2] without the aim of generating any controversy. Furthermore, we would like to recognize the authors of [1] as pioneers in applying the repetitive control technique to the power electronics field [3] [4]

Although most of the things discussed in [1] are correct, we would like to clarify the following.

- As stated in our previous works [2], [5] the odd-harmonic repetitive controller (RC) should only be used in systems which generate or handle signals which do not contain even harmonics. The example presented in [1] does generate even harmonics (including dc frequency), so it is not adequate to use this example to validate the odd-harmonic RC performance. Anyway, nonlinear electrical loads with even harmonics are not usual and their use must be precluded in ac networks for obvious reasons.
 - In [1], it is said "Hence, it is inappropriate to conclude that a traditional RC brings a waste of control effort and reduction of system robustness without improving system performance."
- The capacity to follow certain references or reject certain disturbances is provided by the fact of having high gain in the open-loop transfer function. Unfortunately, high gain and stability are, in general, opposed characteristics. When a traditional RC is used in systems dealing only with odd-harmonic signals high gain appears also in even harmonics (including dc frequency), and, as a consequence, all noise entering in the feedback channels (i.e., measurement noise) at those frequencies will appear amplified in the control signal, and then, in the output of the system.

It is important to remember that power electronics systems are always subject to measurement noise, i.e., noisy sensors or induced electromagnetic disturbances.

Usually, control engineers tend to omit the derivative part of PID controllers in noisy systems. In the same way, we should omit the high gain in those frequencies which is not needed.

- Many industrial systems, such as inverters with output voltage measurement with a voltage transformer or inverters with an output power transformer, include a derivator in their open-loop transfer function. If those systems are combined with a traditional RC, the system will not be internally stable [6] due to the cancellation between the pole at dc frequency from the RC and the zero at dc frequency from the plant and the sensor dy-

namics. This phenomena is not analyzed in traditional repetitive stability analysis, thus when this technique is applied to control power electronics inverters a nonzero finite dc gain in the open-loop transfer function of the averaged plant-sensor dynamics is implicitly assumed.

- Traditional design of a RC is based on the small-gain theorem by, for example, applying an infinite norm over a certain system. This approach is very conservative, so other robustness measures have been used in the analysis of RCs [7]. These quantitative measures generate different values for the odd-harmonic and traditional RCs. In general, the measure obtained with the odd-harmonic RC is better, or at least equal to, one obtained with the traditional RC.

REFERENCES

- [1] K. Zhou, Y. Ye, and D. Wang, "Concerning odd-harmonic digital repetitive control of a single-phase current active filter," *IEEE Trans. Power Electron.*, vol. 20, no. 2, pp. 511–513, Mar. 2005.
- [2] R. Costa-Castello, R. Griño, and E. Fossas, "Odd-harmonic digital repetitive control of a single-phase current active filter," *IEEE Trans. Power Electron.*, vol. 19, no. 4, pp. 1060–1068, Jul. 2004.
- [3] K. Zhou and D. Wang, "Digital repetitive learning controller for three phase cvcf pwm inverters," *IEEE Trans. Ind. Electron.*, vol. 48, no. 4, pp. 820–830, Aug. 2001.
- [4] K. Zhou, K. S. Low, and D. Wang, "Periodic errors elimination in cvcf pwm dc/ac converter systems: A repetitive control approach," *Proc. Inst. Elect. Eng.*, vol. 147, no. 6, pp. 694–700, Nov. 2000.
- [5] R. Griño and R. Costa-Castello, "Digital repetitive plug-in controller for odd-harmonic periodic references and disturbances," *Automatica*, vol. 41, no. 1, pp. 153–157, Jan. 2005.
- [6] J. C. Doyle, B. A. Francis, and A. R. Tannenbaum, *Feedback Control Theory*. New York: Macmillan, 1992.
- [7] G. Hillerström and R. C. Lee, "Tradeoffs in repetitive control," Tech. Rep. CUED/F-INFENG/TR 294, Univ. Cambridge, Cambridge, U.K., Jun. 1997.



Ramon Costa-Castelló (M'02) was born in Lleida, Spain, in 1970. He received the M.Sc. and Ph.D. degrees in computer science from the Universitat Politècnica de Catalunya (UPC), Barcelona, Spain, in 1993 and 2001, respectively.

Since July 1996, he has been teaching different topics in digital control and real-time systems at the Universitat Politècnica de Catalunya. His research interests include digital control, mechanical systems control, and nonlinear control.

Dr. Costa-Castelló is a Member of SIAM and an

Affiliate Member of IFAC.



Robert Griño (M'99) received the M.Sc. degree in electrical engineering and the Ph.D. degree in automatic control from the Universitat Politècnica de Catalunya (UPC), Barcelona, Spain, in 1989 and 1997, respectively.

From 1990 and 1991, he was a Research Assistant at the Instituto de Cibernética (UPC). From 1992 to 1998, he was an Assistant Professor with the Systems Engineering and Automatic Control Department, Institute of Industrial and Control Engineering, Universitat Politècnica de Catalunya, where he has been an

Associate Professor since 1998. His research interests include digital control, sensitivity theory, and nonlinear control.

Dr. Griño is an Affiliate Member of IFAC.

Manuscript received April 28, 2005; revised October 7, 2005. This work was supported in part by the Comisión Interministerial de Ciencia y Tecnología (CICYT) under Projects DPI2004-06871-C02-02 and DPI2002-03279. Supported by Associate Editor V. Staudt.

The authors are with the Institut d'Organització i Control de Sistemes Industrials, Universitat Politècnica de Catalunya, Barcelona, Spain (e-mail: ramon.costa@upc.edu; roberto.grino@upc.edu; enric.fossas@upc.edu).

Digital Object Identifier 10.1109/TPEL.2006.876781



Enric Fossas received the M.S. and Ph.D. degrees in mathematics from Barcelona University, Barcelona, Spain, in 1981 and 1986, respectively.

Since 1981, he has instructed mathematics at Barcelona University and mathematics and automatic control in the Universitat Politècnica de Catalunya, Barcelona, where he is currently an Assistant Professor. His research interests are in the field of system theory (VSS) and control from a mathematical viewpoint.